A multi-platform perspective of precipitation measurement and estimation
Cyprus participation in GV

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CYPRUS METEOROLOGICAL SERVICE

Aims of this presentation:

Expose the capabilities of the Cyprus Met. Service in a GV effort

•Present some of the results of the Voltaire Project (funded by EU) as focused on the island of Cyprus as related to GV

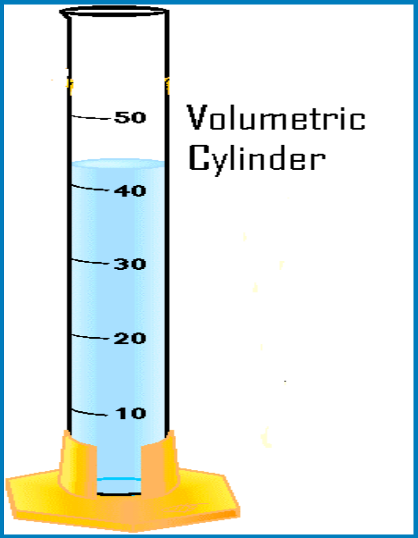
•Present potential partners in GV participation and their capabilities

Credit must be given to my collaborators with whom we co-operated during Voltaire Project for the methodologies and findings reported in this presentation:

MARCO GABELLA, GIOVANNI PERONA, JÜRG JOSS
PETROS CONSTANTINIDES, VITTORIO CALVIA,
RICCARDO NOTARPIETRO, THOMAS EINFALT,
CLAUDIA GOLTZ, TAKIS KASPARIS

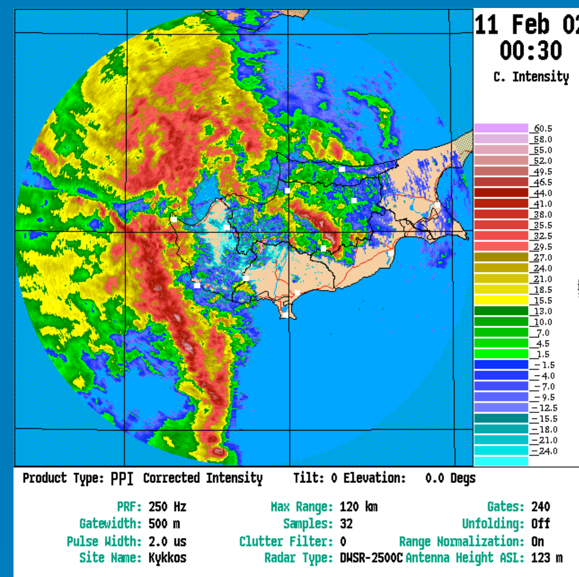
5°W
0°
5°E
10°E
15°E
20°E
25°E
30°E
35°E
45°N
40°N
35°N
30°N
GERMANY
CZECH
SLOVAKIA
Carpathian Mountains
UKRAINE
MOLDOVA
AUSTRIA
HUNGARY
ROMANIA
FRANCE
Alps
Bay of Biscay
Pyrenees
ANDORRA
SPAIN
PORTUGAL
ITALY
SAN MARINO
Apennines
Corsica
Majorca
Tyrrhenian Sea
Adriatic Sea
Mediterranean Sea
Black Sea
BULGARIA
ALBANIA
GREECE
Aegean Sea
TURKEY
Ionian Sea
Monte Etna
MALTA
TUNISIA
Crete
Rhodes
CYPRUS
SYRIA
LEBANON
JORDAN
SAUDI ARABIA
MOROCCO
Atlas Mountains
Grand Erg Occidental
Grand Erg Oriental
ALGERIA
LIBYA
EGYPT
Sahara Desert

Available Platforms for Precipitation Measurement / Estimation: Raingauges



CYPRUS IN VOLTAIRE: A dense network of Raingauges collect precipitation and from its volume measurement convert into height (mm)

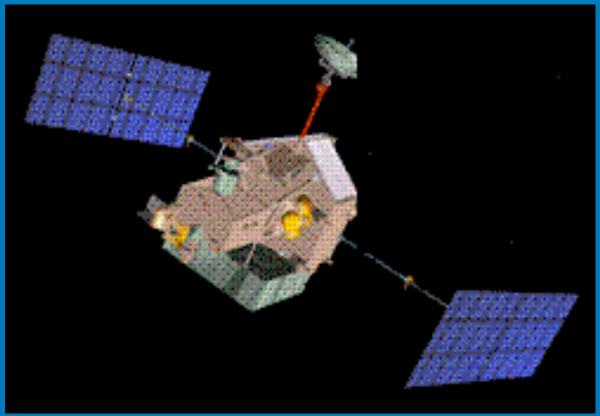
Available Platforms for Precipitation Measurement / Estimation: Ground Radar

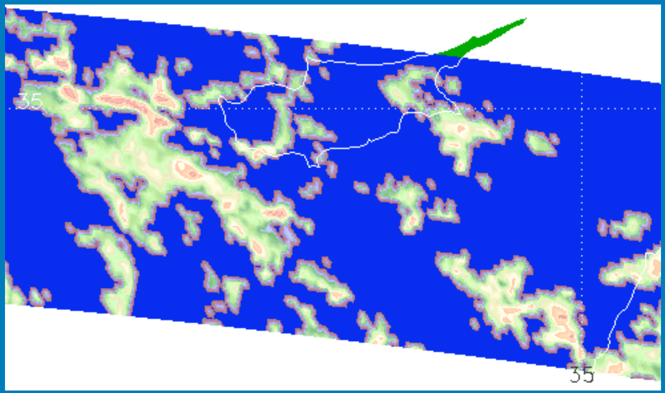


CYPRUS IN VOLTAIRE: C-band Doppler Located at Kykkos records reflectivities from hydrometeors (dBZ)

Available Platforms for Precipitation Measurement / Estimation:

TRMM (Tropical Rainfall Measuring Mission) PR (13.8 GHz radar)



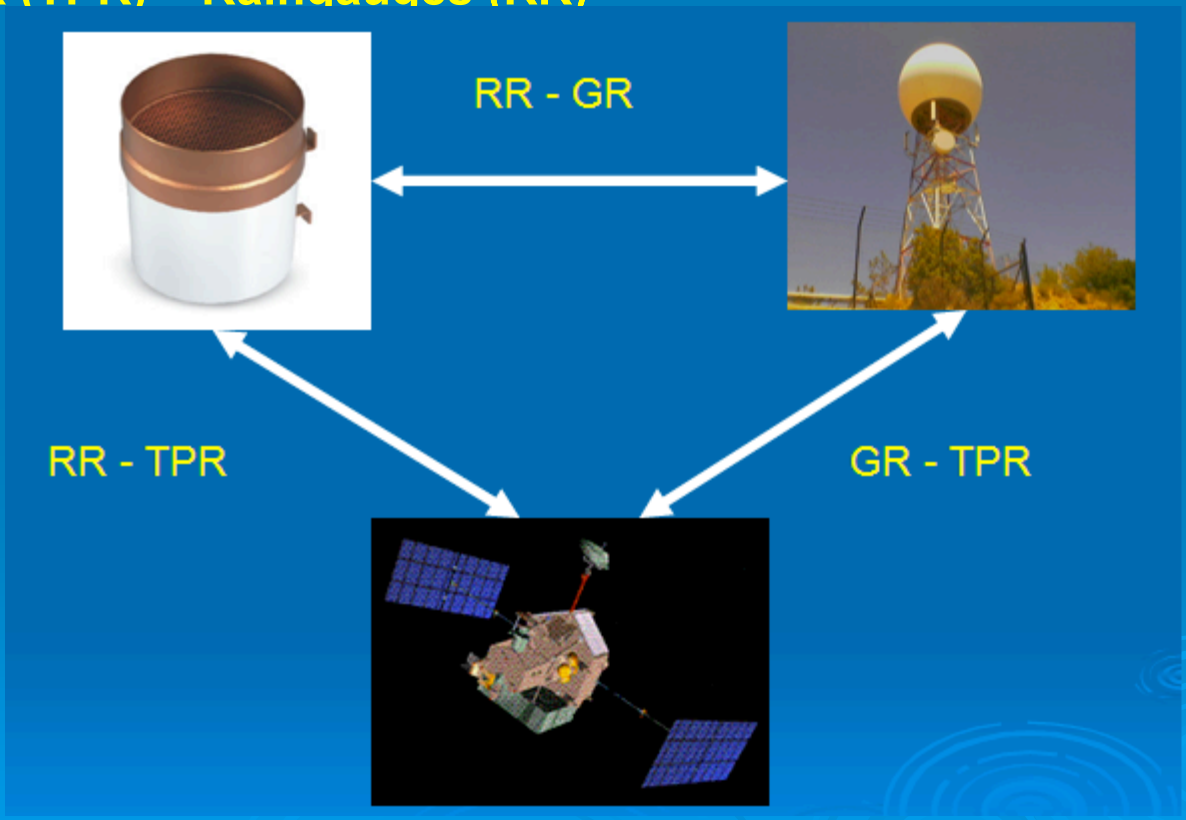


CYPRUS IN VOLTAIRE: A European country under the swath of TRMM

Spaceborne TRMM PR Product 2A25 is used and the parameter *NearSurfZ*

A MAJOR EFFORT IN VOLTAIRE WAS TO Compare-adjust measurements- estimations of ppn

- **Raingauges (RR) – Ground radar (GR)**
- **Ground Radar (GR) – TRMM PR (TPR)**
- **TRMM PR (TPR) – Raingauges (RR)**



1

Rain gauge network

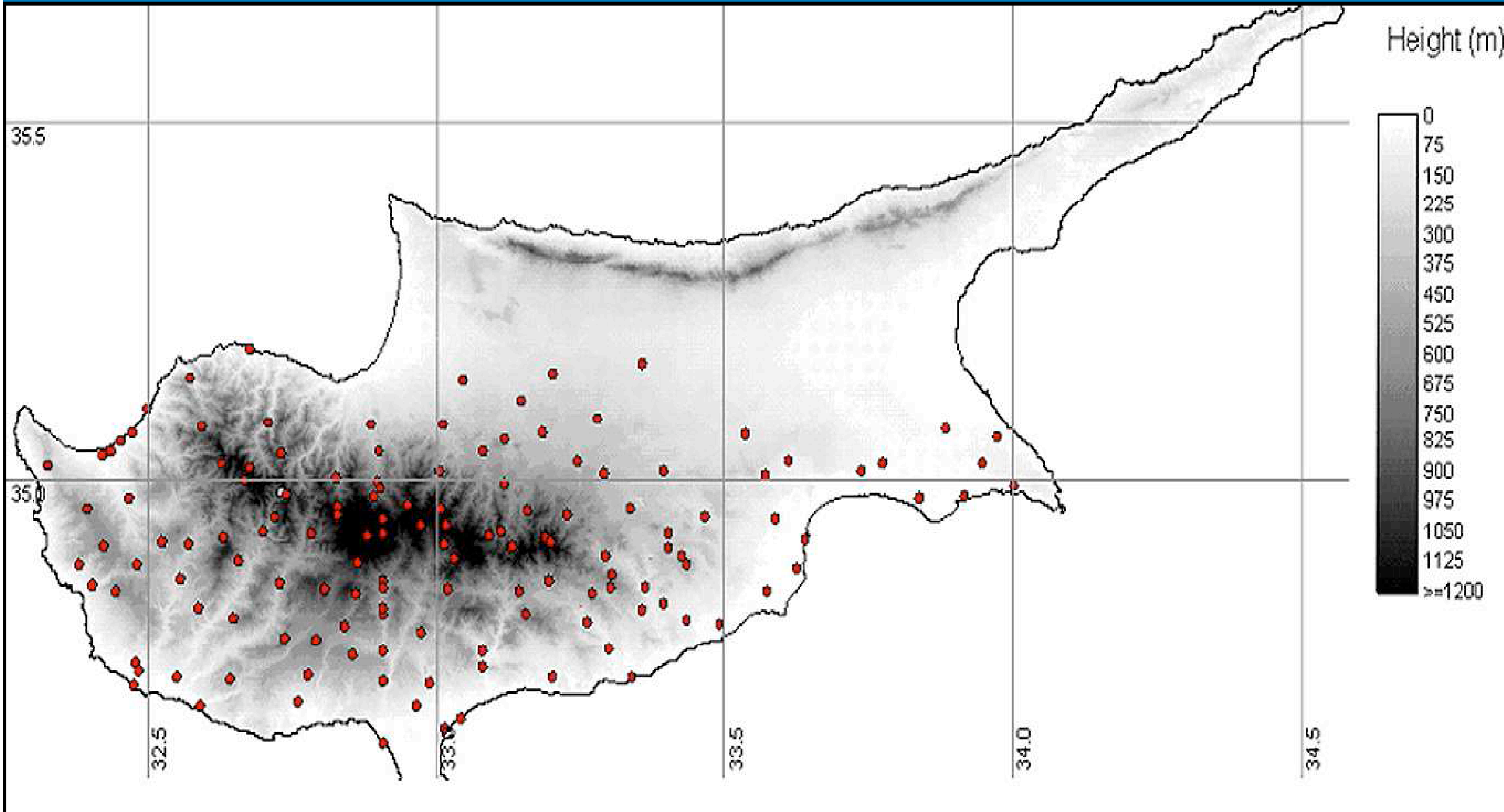
versus

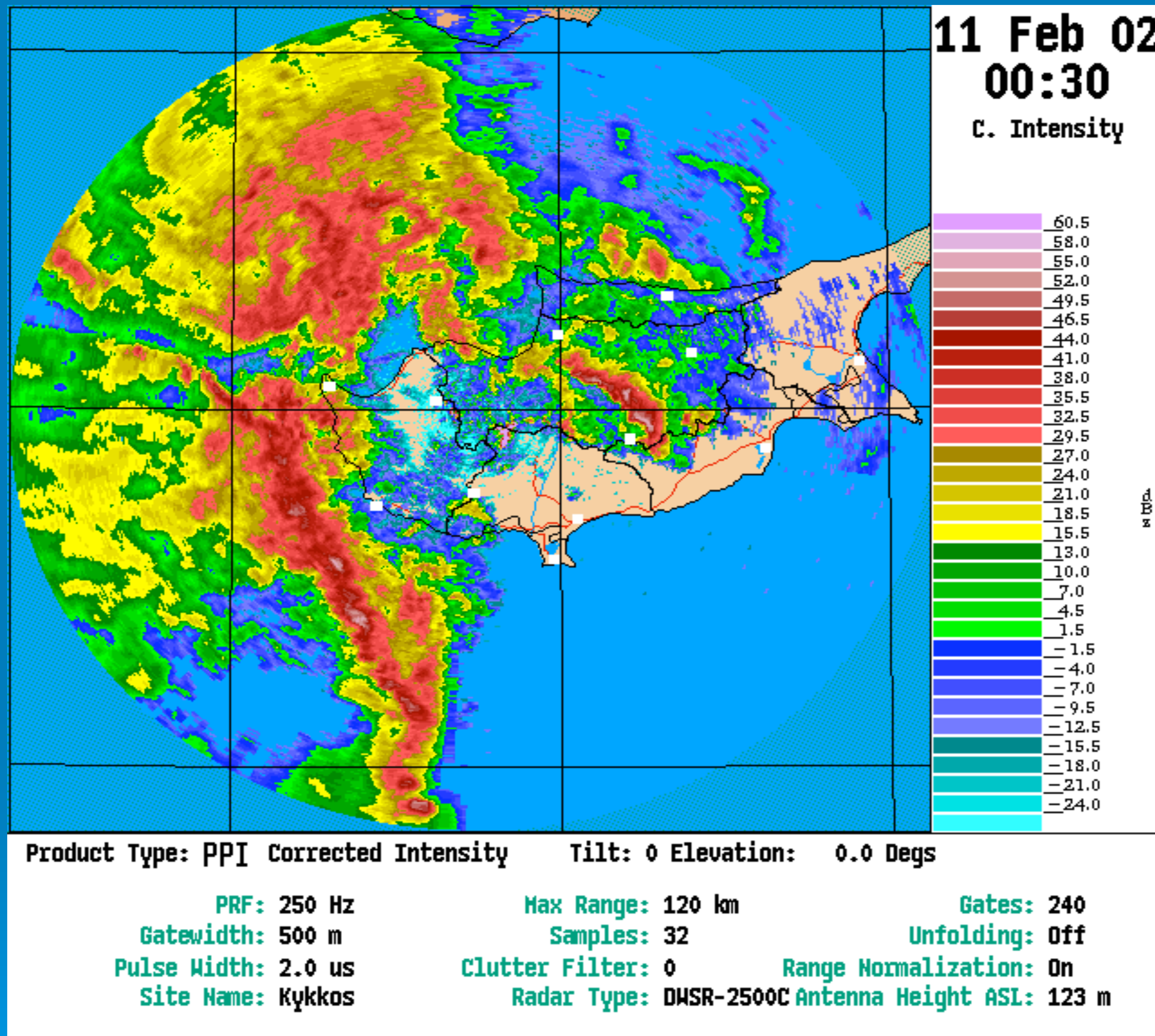
Ground Radar

▼ Having both radar and rain-gauge data available, the natural reaction is to adjust radar data by comparing it to rain gauge data commonly referred to as “ground truth”.

▼ Most radar data adjustment methods are supplemented with ground validation using data from rain gauges. But how true are these measurements?

Rain-gauge network (145 gauges)





11 Feb 02
00:30
C. Intensity
60.5
58.0
55.0
52.0
49.5
46.5
44.0
41.0
38.0
35.5
32.5
29.5
27.0
24.0
21.0
18.5
15.5
13.0
10.0
7.0
4.5
1.5
−1.5
−4.0
−7.0
−9.5
−12.5
−15.5
−18.0
−21.0
−24.0
dBz
Product Type: PPI Corrected Intensity
Tilt: 0 Elevation: 0.0 Degs
PRF: 250 Hz
Gatewidth: 500 m
Pulse Width: 2.0 us
Site Name: Kykkos
Max Range: 120 km
Samples: 32
Clutter Filter: 0
Radar Type: DWSR-2500C
Gates: 240
Unfolding: Off
Range Normalization: On
Antenna Height ASL: 123 m

To obtain accurate radar data that will be useful for rainfall estimation, it is evident that we need methods that will allow us to accurately convert reflectivity measurements, *Z*, into rainfall, *R*.

Numerous methods to get the Z-R relations:

1. Calibrate both rainfall rate and radar reflectivity factor are derived from raindrop size distribution (DSD) observations, typically made at the surface and representing a sample volume,
2. Directly derived relationship between radar reflectivities and surface rain gauge observations (Power Law, regressions, Neural Networks etc),
3. Polarimetric method to simultaneously measure reflectivity and phase at H and V polarization, and using multi-frequency,

……………….etc

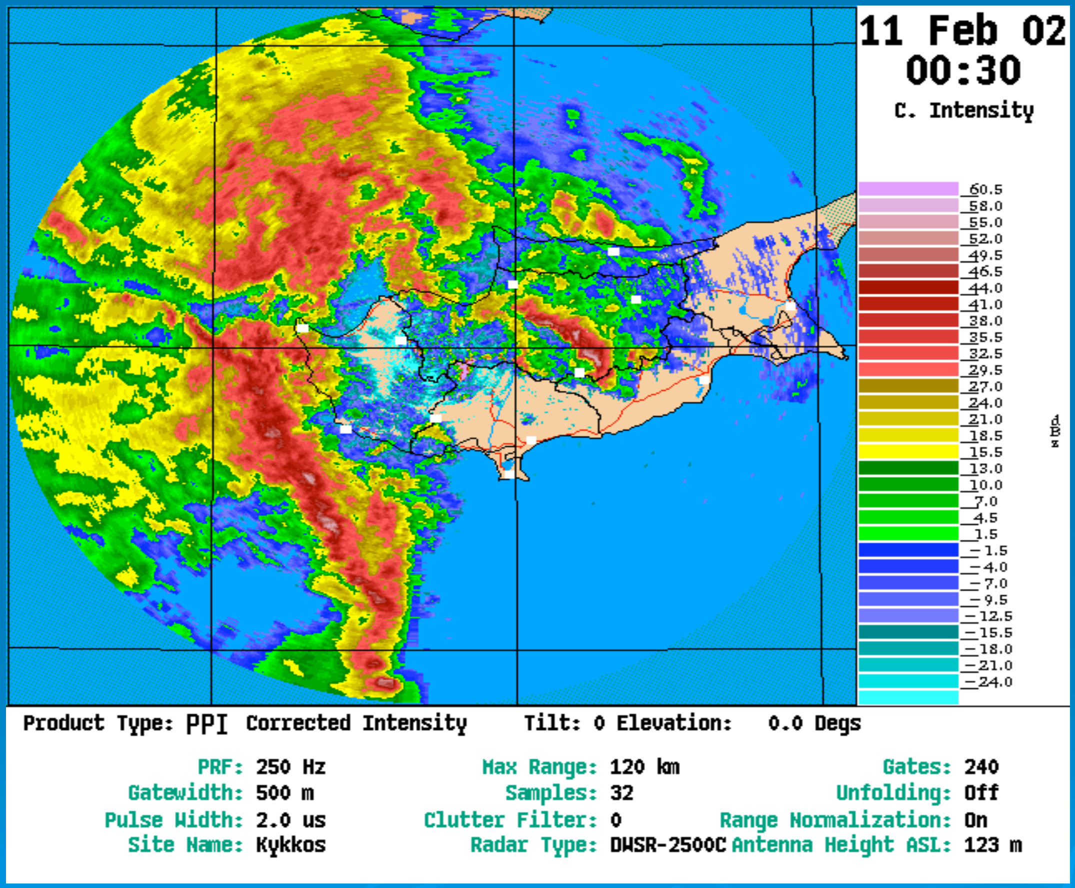
The reflectivity Z obtained by the radar is converted into rain rate R through the following formula,

$$R = \sqrt[3]{\left(\frac{Z}{316}\right)^2}$$

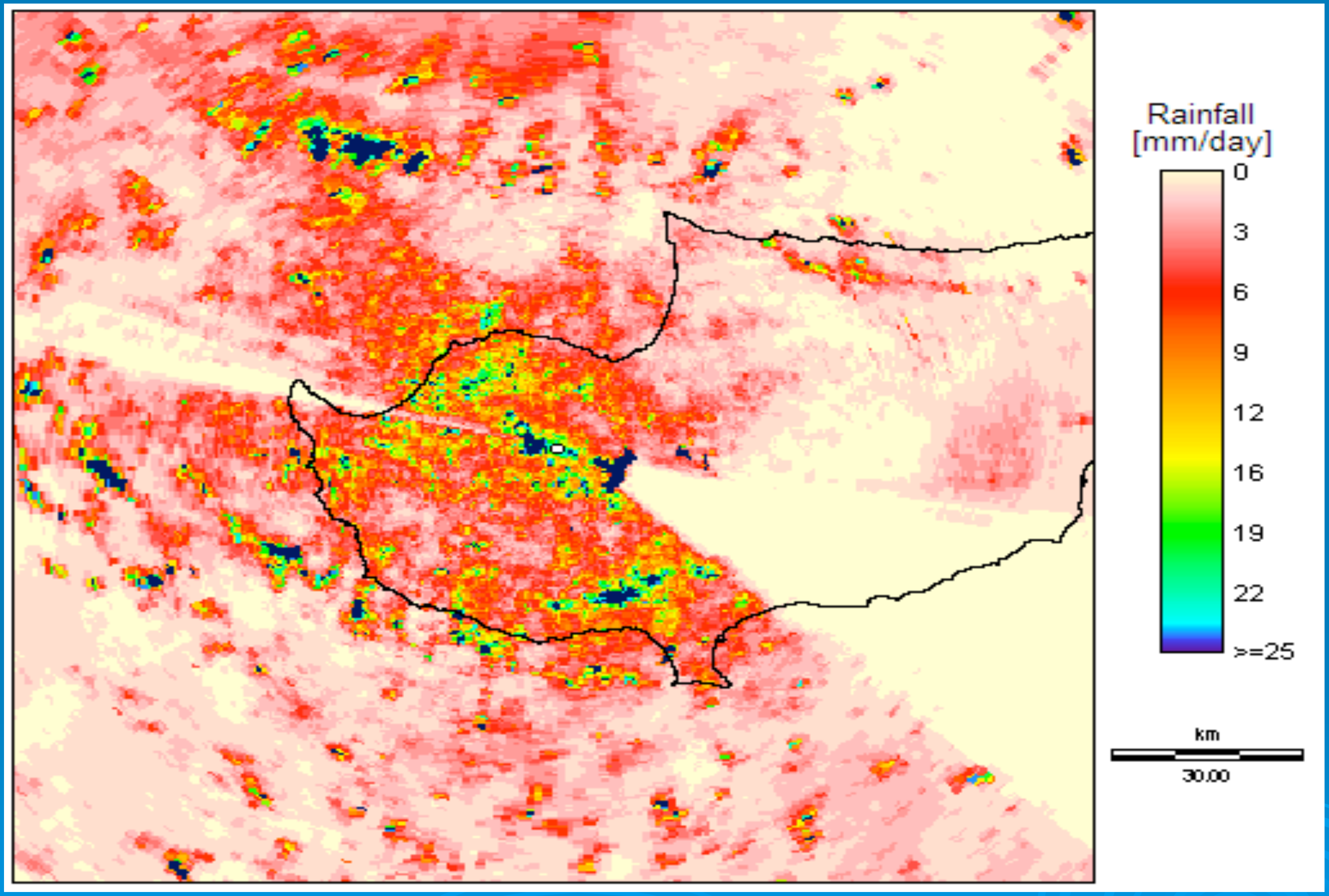
R is measured in mm/h and Z is measured in $mm^6\ m^{-3}$

Using the power law radar data were converted into rain rates

ORIGINAL RADAR DATA dBZ

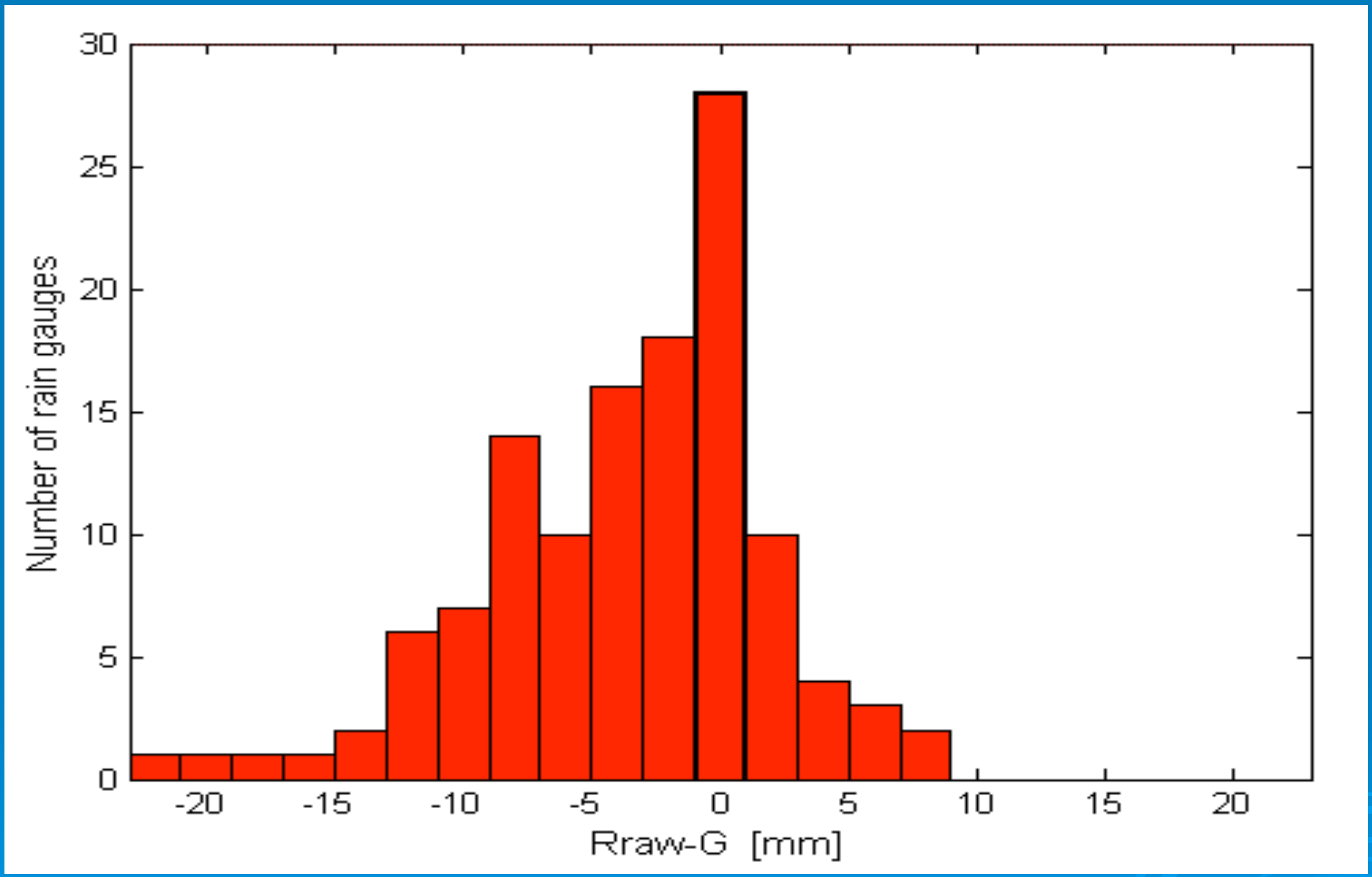


Daily rainfall for 11th February, 2002 by using the Power Law.



Comparing rain rates (R-Radar) to rain gauge (G) measurements without Quality Control:

Large differences are observed.



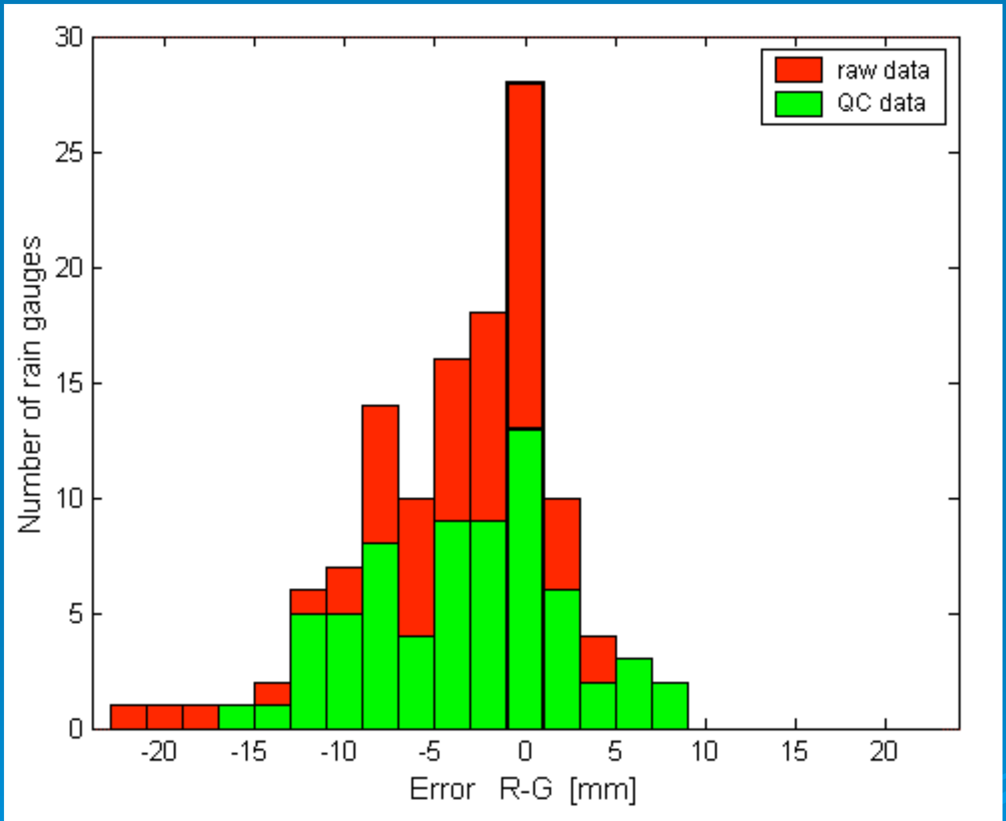
Quality Control of Rain Gauge data:

To improve the comparison, simple selection of the proper stations was a necessary first step for a complex orography environment like Cyprus.

RAINGAUGES EXCLUDED FROM THE COMPARISON – SELECTION CRITERIA

- Rain gauges with beam occultation over 75%;
- Rain gauges with strong ground clutter;
- Rain gauges whose R value is less than 0.2 mm;
- Rain gauges whose G value is less than 1 mm;
- 3 outliers, whose R and G values are quite different from each other;

IMPROVED COMPARISON WITH SIMPLE RAINGAUGE SELECTION



•More careful Quality Control

Correction methods

Clutter (ground, negative ground, sea)

beam blockage / shielding

anaprop

attenuation

overshooting

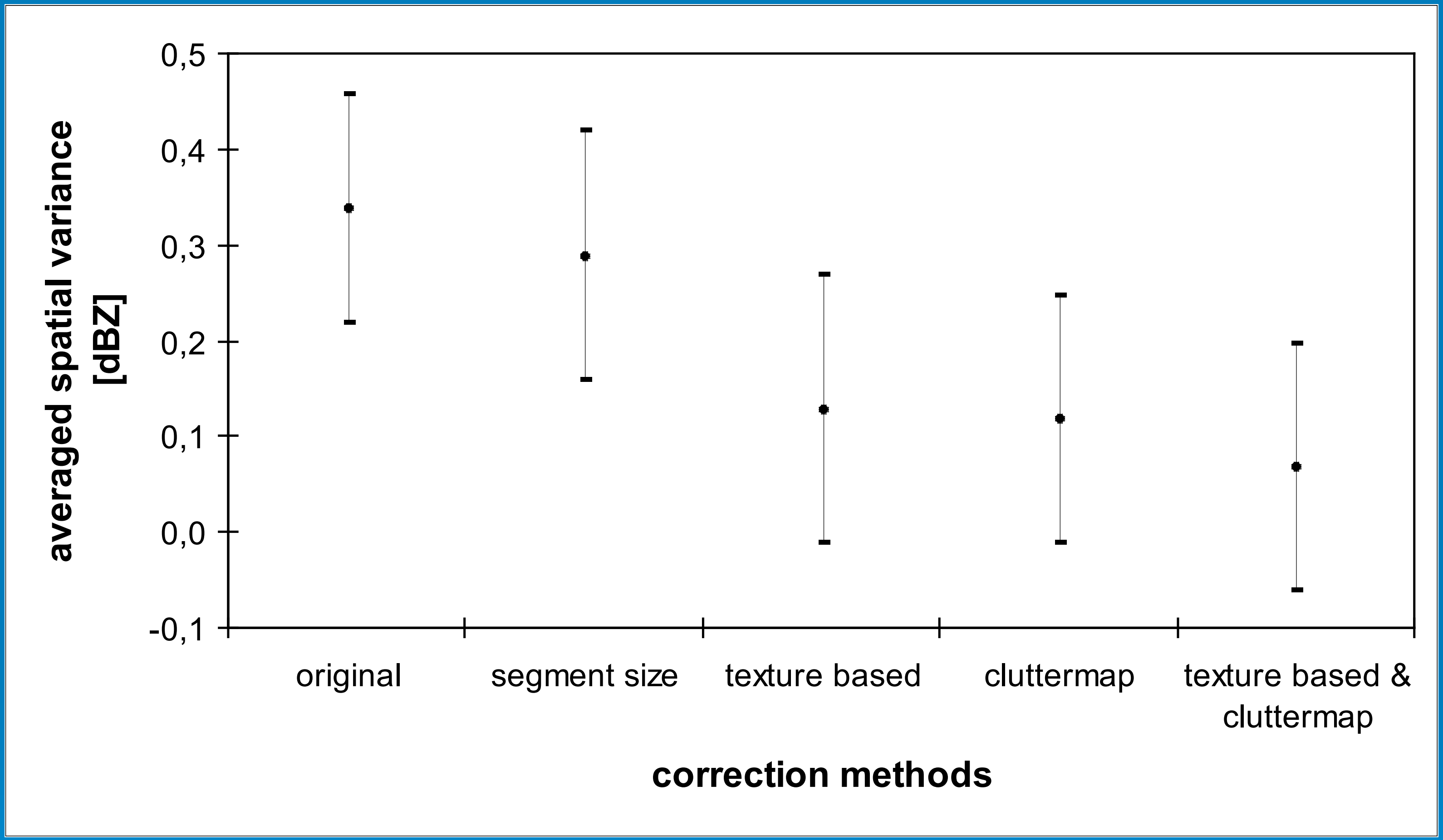
bright band / VPR

speckle, birds, insects

A **«cluttermap»** contains the image pixels, which are constantly or in most cases influenced by ground clutter, e.g. high buildings or mountains.

The **«texture-based»** algorithm detects small areas like speckles, which have a high gradient to the neighbourhood. It helps also to remove artefacts on radar images, e.g. thin lines.

The algorithm **«segment size»** is a speckle filter. It computes the number of connected image pixels with values greater than zero constituting a "segment".



averaged spatial variance
[dBZ]
0,5
0,4
0,3
0,2
0,1
0,0
-0,1
original
segment size
texture based
cluttermap
texture based &
cluttermap
correction methods

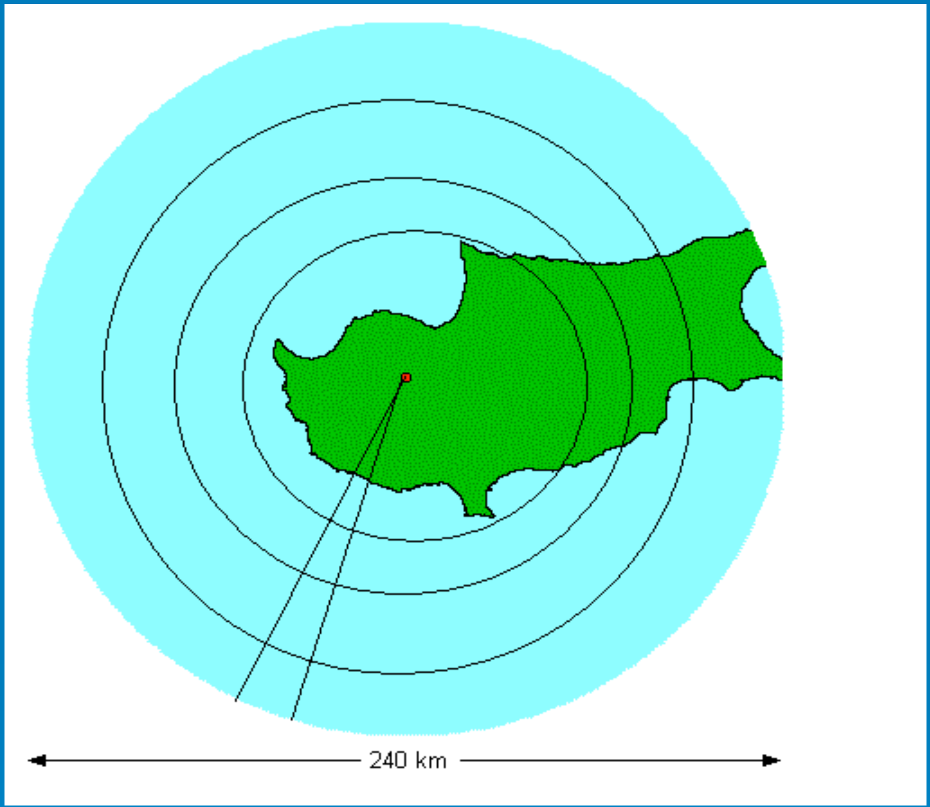
2

Ground Radar versus TRMM PR

The differences between the two instruments are large:

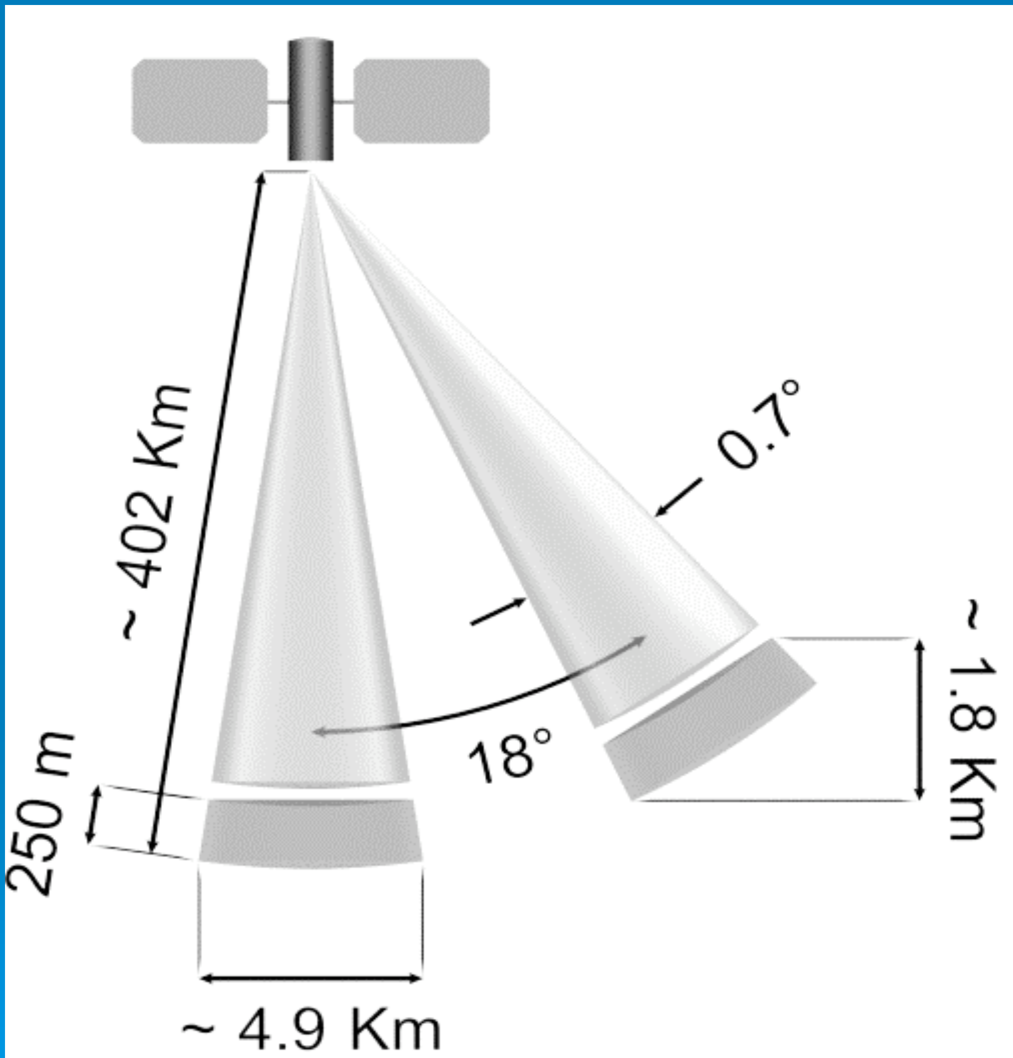
- different frequency of operation,
- sampling volume,
- geometrical viewing angles,
- attenuation,
- sensitivity and
- time of acquisition
- horizontal resolution (pixel size)

The Ground-based Radar (GR) measures rain from a lateral direction



GR measures rain from close to the radar up to large distances from the radar (e.g. up to 120 km). Consequently, the **Scattering volume** of GR changes significantly: it increases the square of the distance from GR

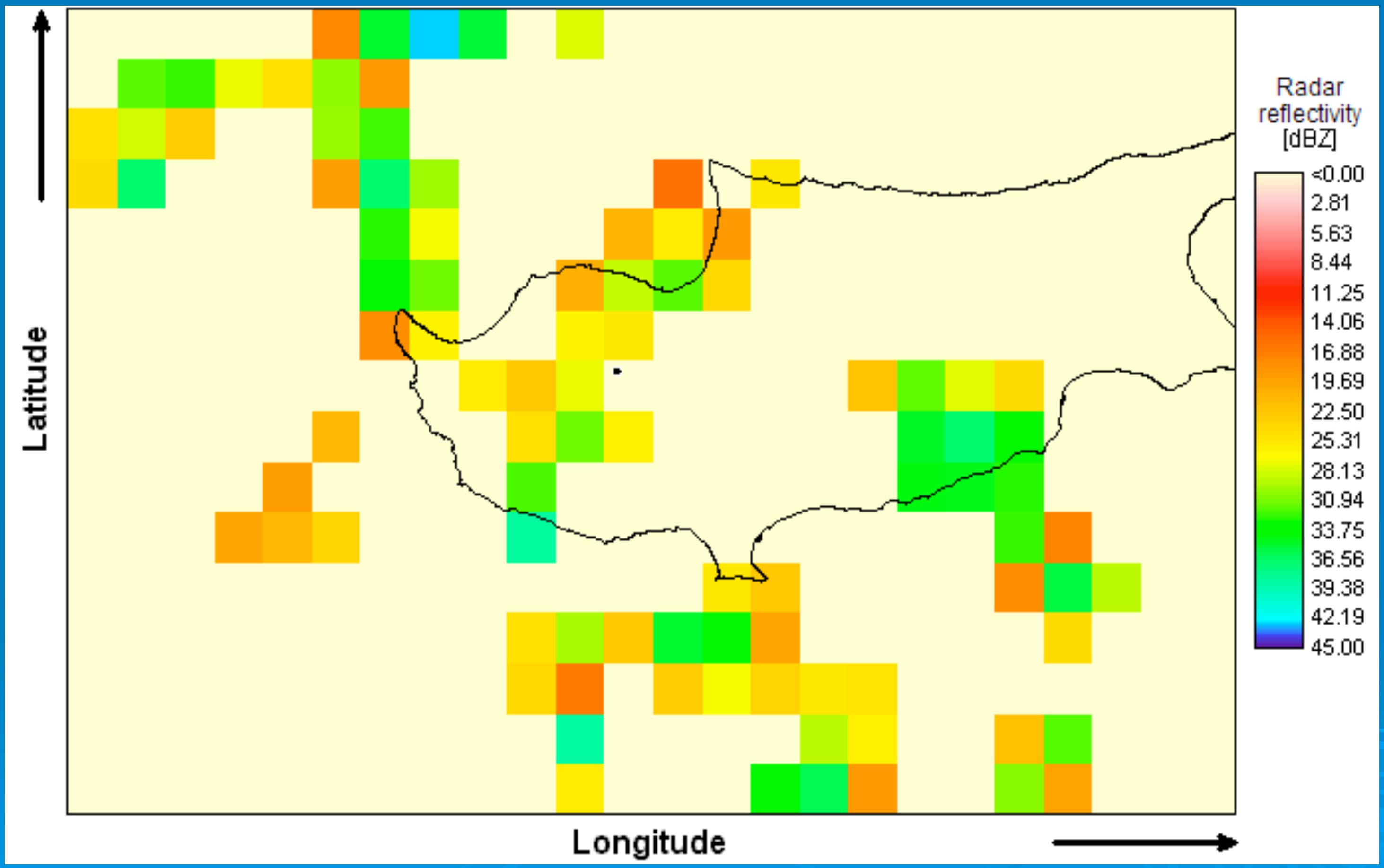
The space-borne radar (TPR) “sees” it from the top.



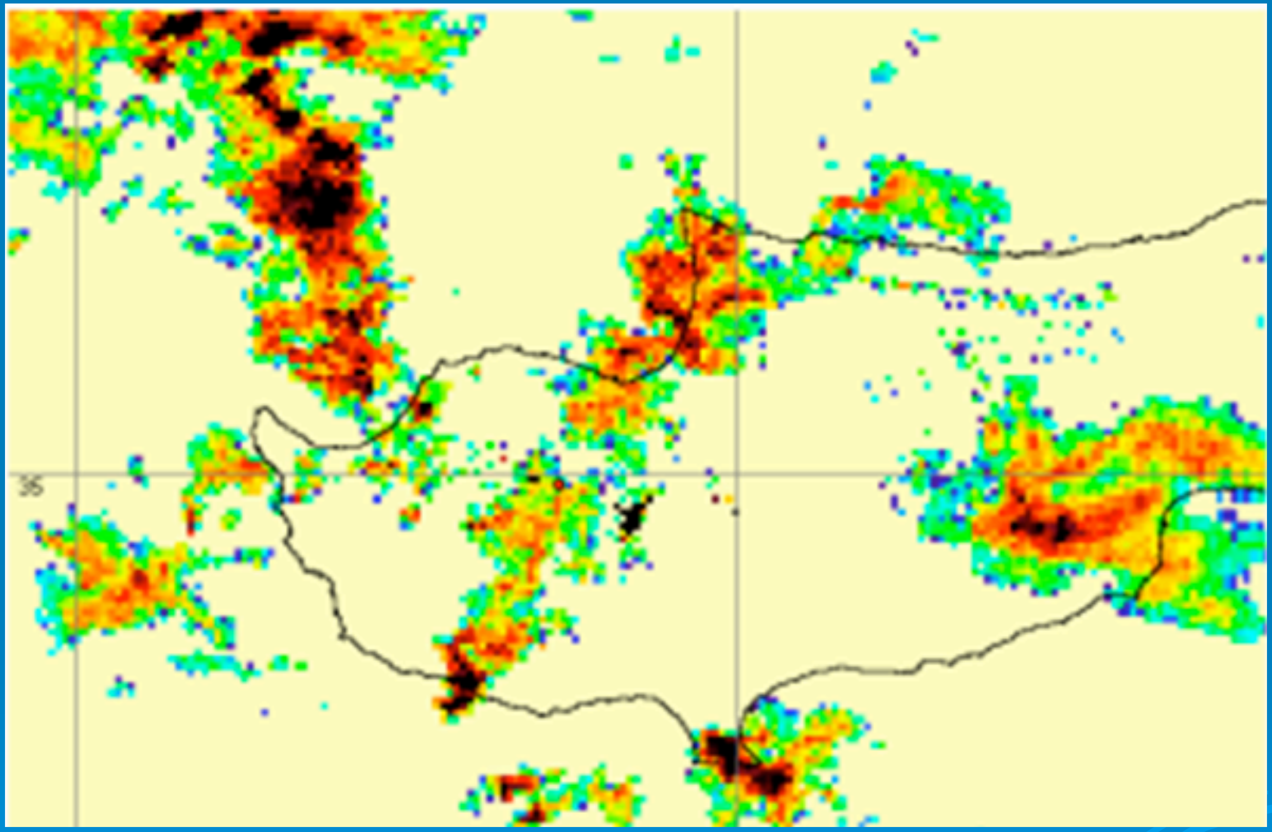
The vertical resolution of TPR results in a minimum of ~250 m at the nadir. However, when the antenna looks across-track, the **vertical resolution** decreases.

TPR

2002, February 11th 2250UTC



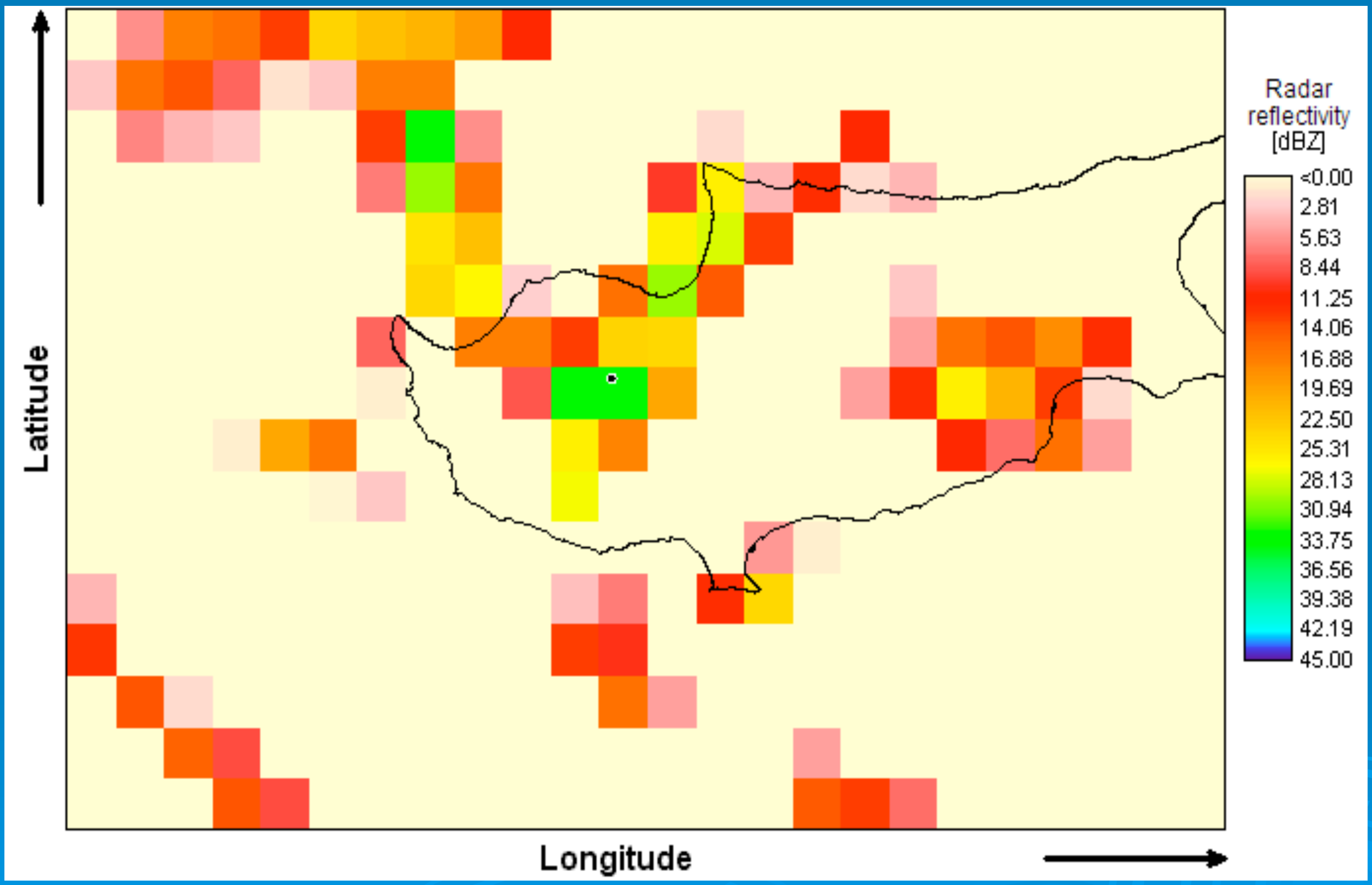
Original Ground Radar
2002, February 11th 2315UTC
500m bin size

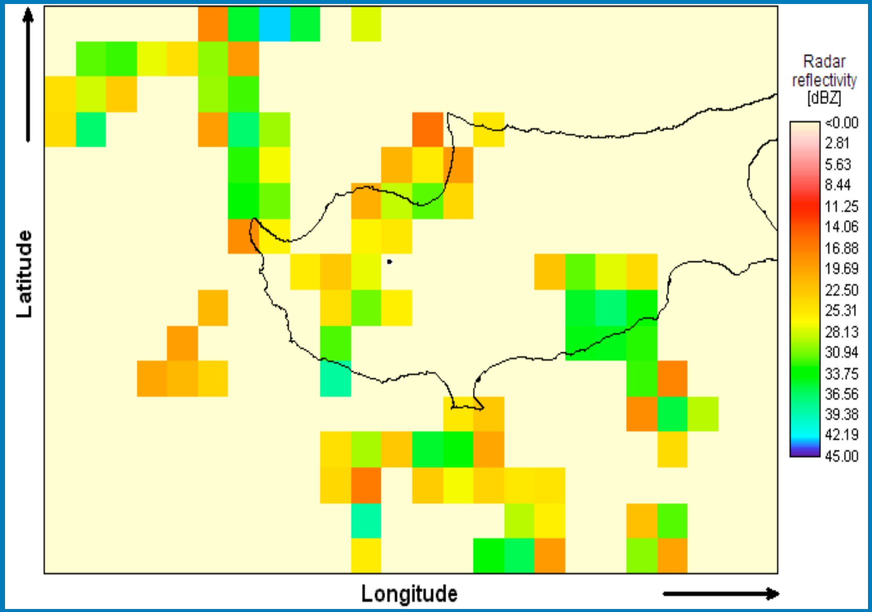


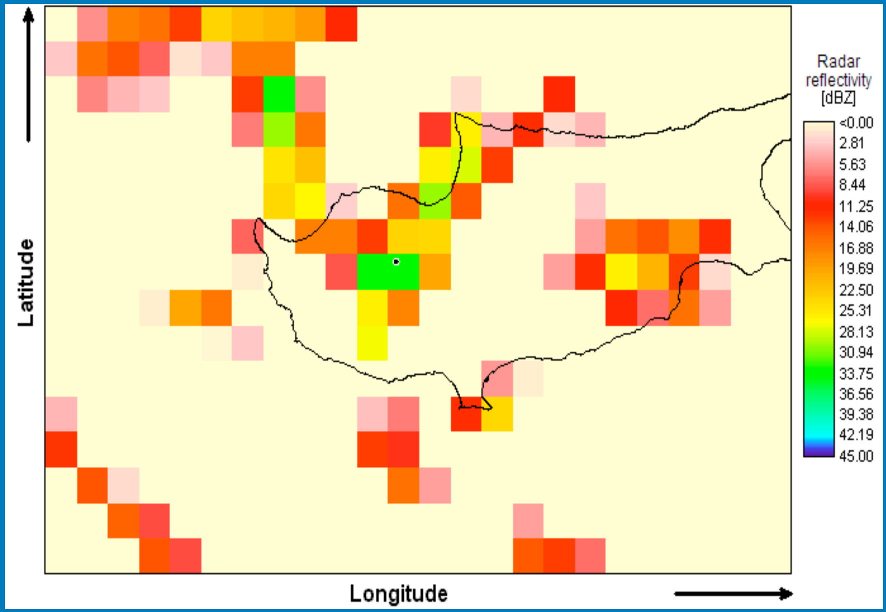
To make the two maps comparable, we apply upscaling to GR

Upscaling is the procedure to create from a number of smaller pixels a representative reflectivity of what a low-resolution process sees in larger pixels.

Upscaling of GR: Simple adjustment of Ground Radar By aggregating: median of 10x10=100 pixels **2002, February 11th** 2315UTC







TPR 2250UTC

GR 2315UTC

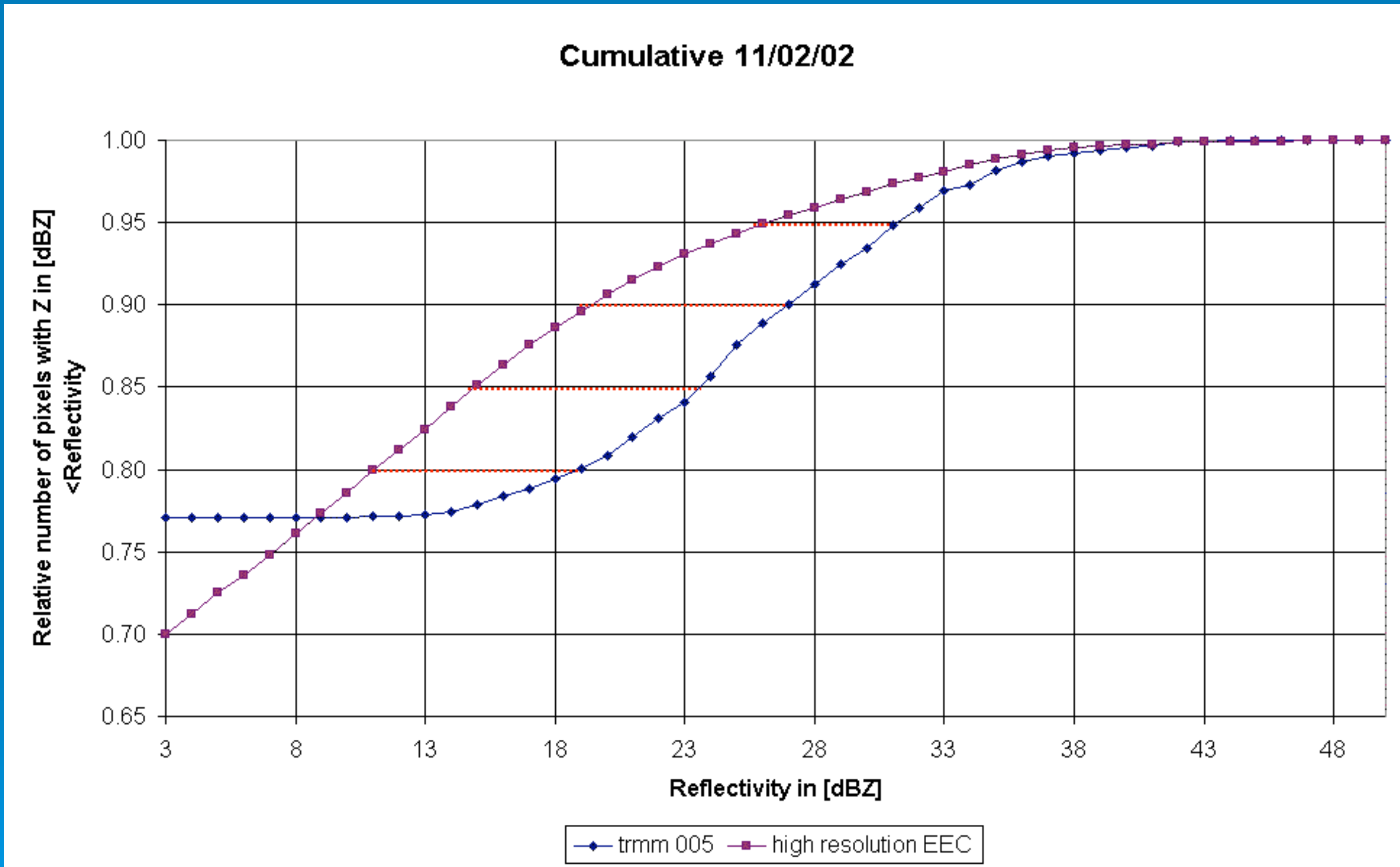
The mean value of each map:

TRMM PR map → 27.4 dBZ

GR map → 10.6 dBZ.

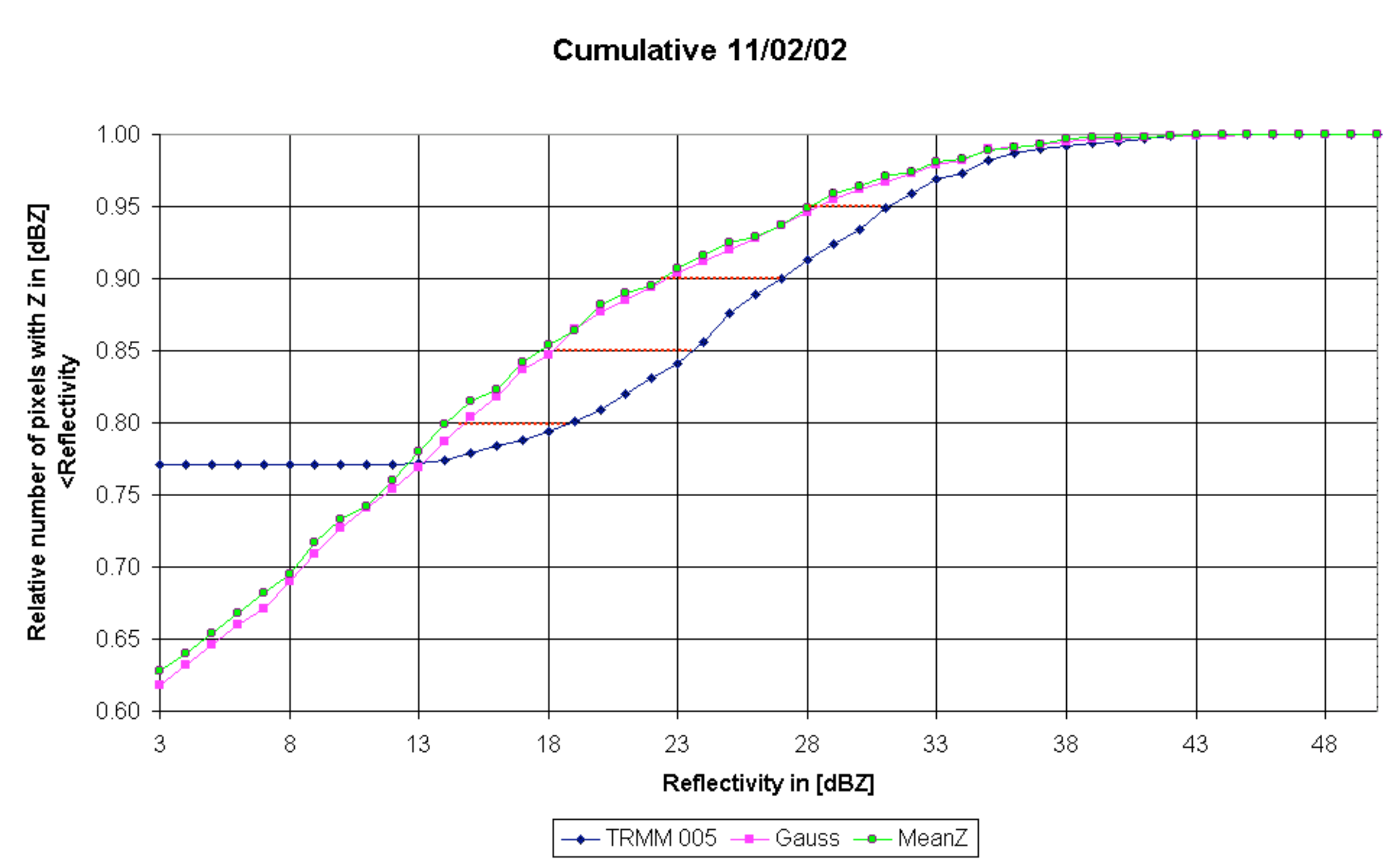
Offset of 17 dBZ (hypothesis: the precipitation moved keeping the same intensity, GR **25 min** later than TPR)

Distribution of bias with cumulative curves



More elaborate upscalaing: Gaussian, MeanZ reduces the differences between the two maps

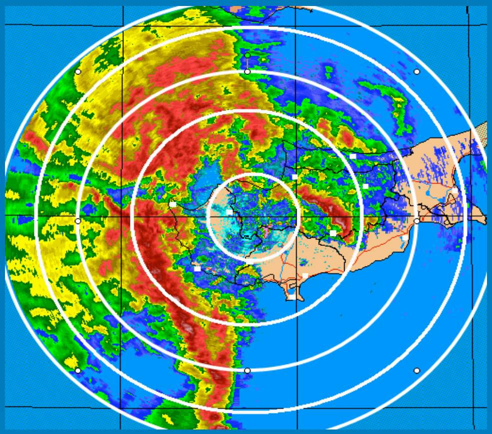
Reduction of bias with Gauss and Mean Upscaling



Adjust GR with TPR?

It sounds reasonable: GR generally stable but can shift (repairs, upgrades etc). The TPR provides independent, stable time series.

- **METHOD:** Regression analysis based on the ratio of the average radar reflectivities of both radars in *circular rings* around the GR.

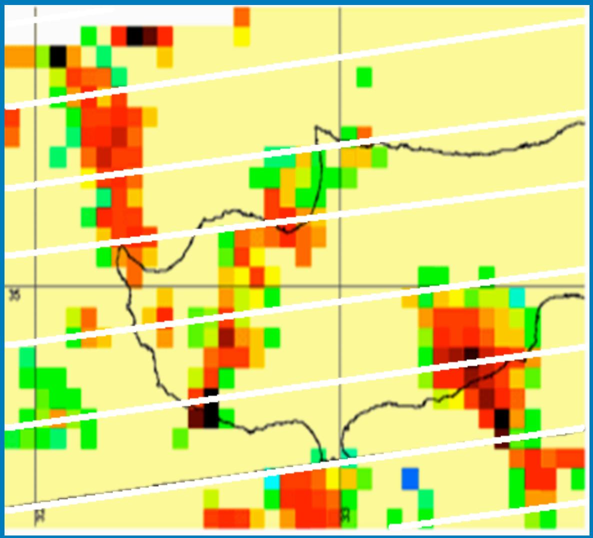


- **RESULT:** Using the TPR for reference, around 10dB have to be added to the measured radar reflectivity Z of GR (when increasing the range from 10 km to 100 km). Instead of an r^2 – dependence we find an apparent r^3 –dependence.

Adjust TPR with GR?

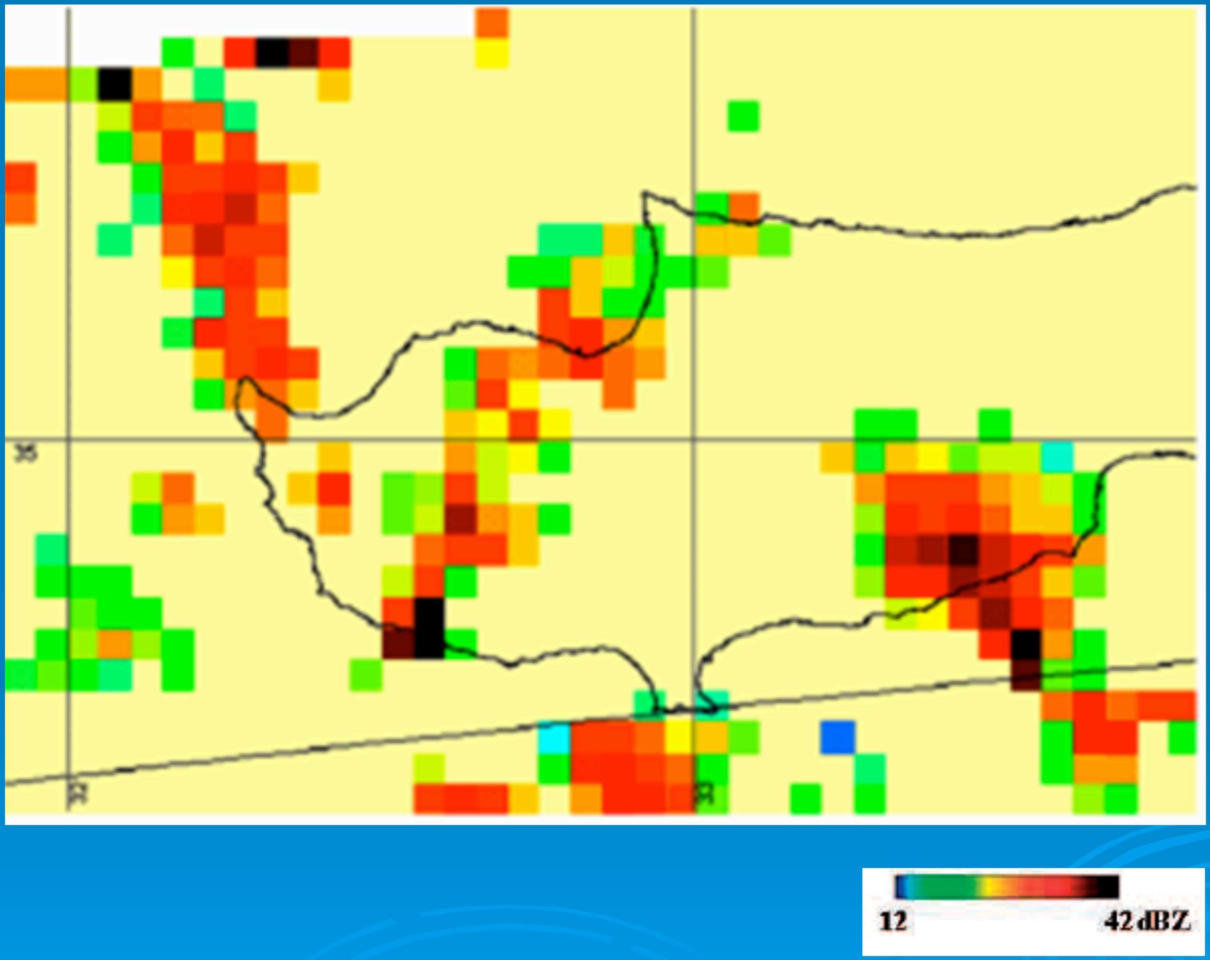
This is also possible:

- **METHOD:** Regression analysis based on the ratio of the average radar reflectivities of both radars in rectangular areas parallel to the Nadir line.
- **RESULT:** Using range-adjusted data of the GR for reference, we find that a few dB have to be added, when increasing the distance from close to Nadir to the edge of the swath (~120 km far away).



Original Lat-Lon display of the TRMM Ku-band precipitation radar (TPR) at 2250UTC on 11 February 2002

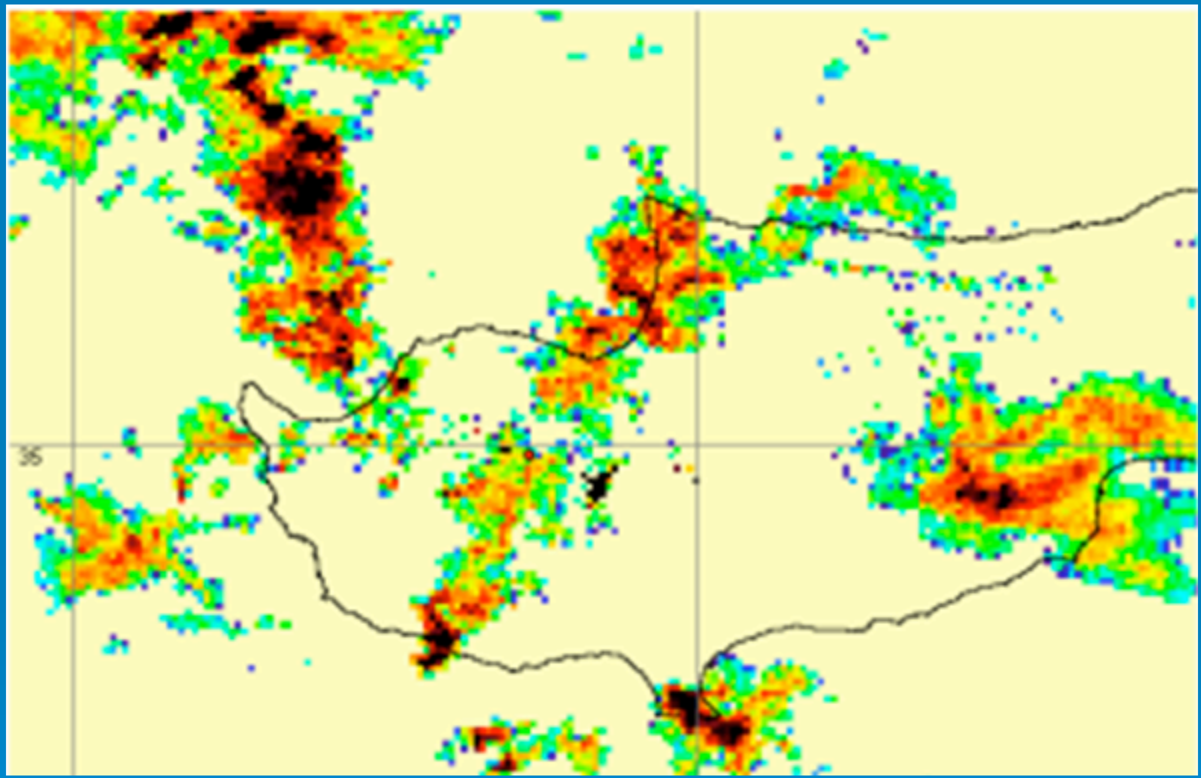
E X A M P L E

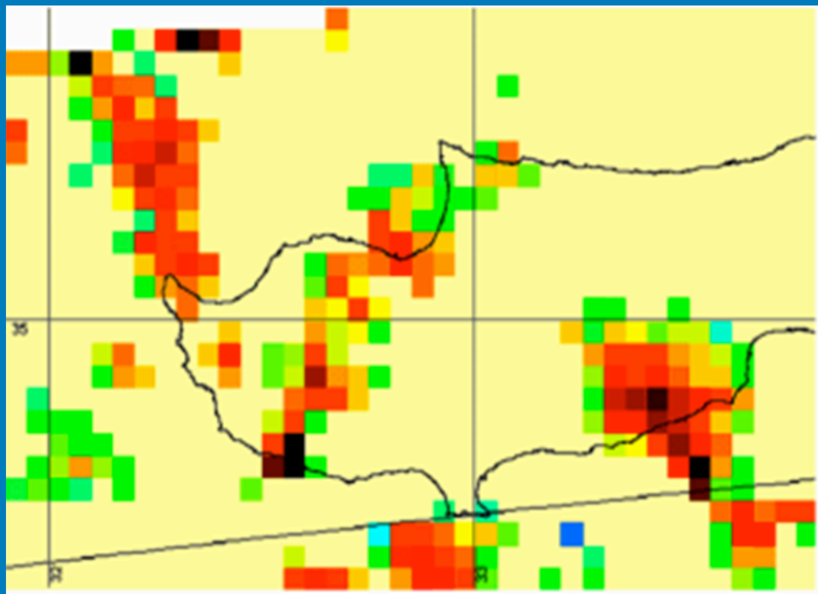


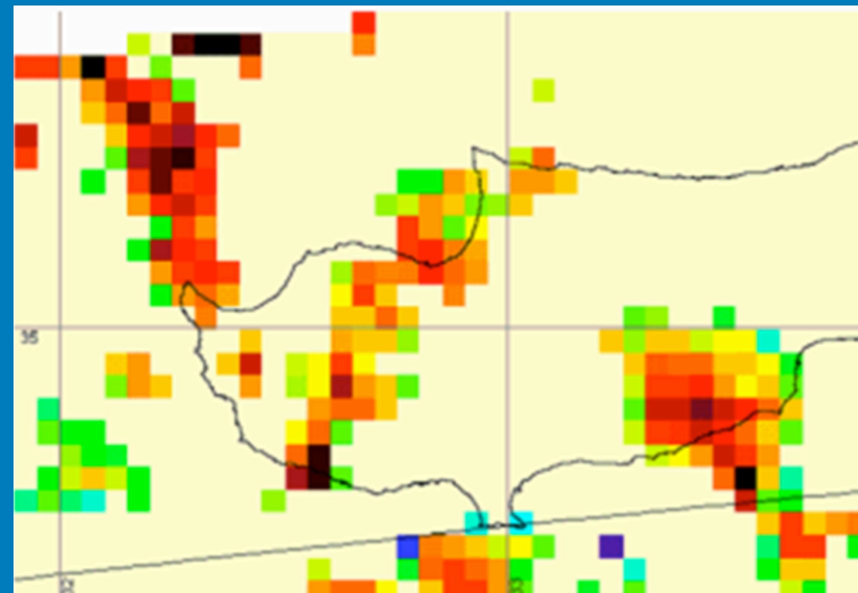
ground track of the satellite at Nadir

Original Ground Radar at Kykkos, 2315UTC on 11 February 2002 TRMM adjusted

E X A M P L E



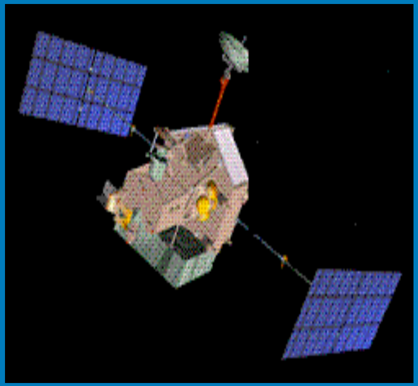




TPR original data

TPR adjusted data with the GR TRMM-adjusted data

3

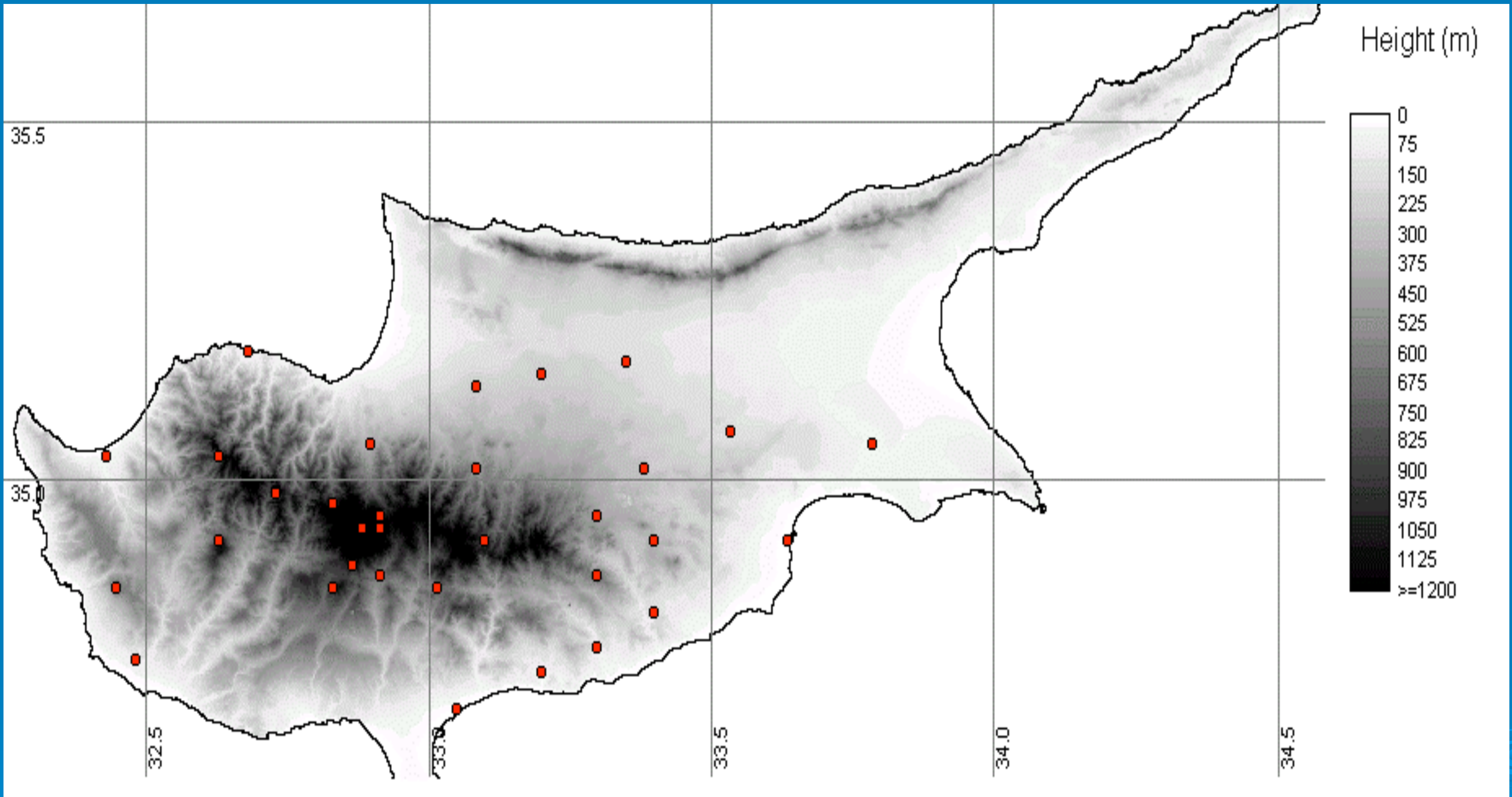


TRMM PR
versus
Rain gauge network

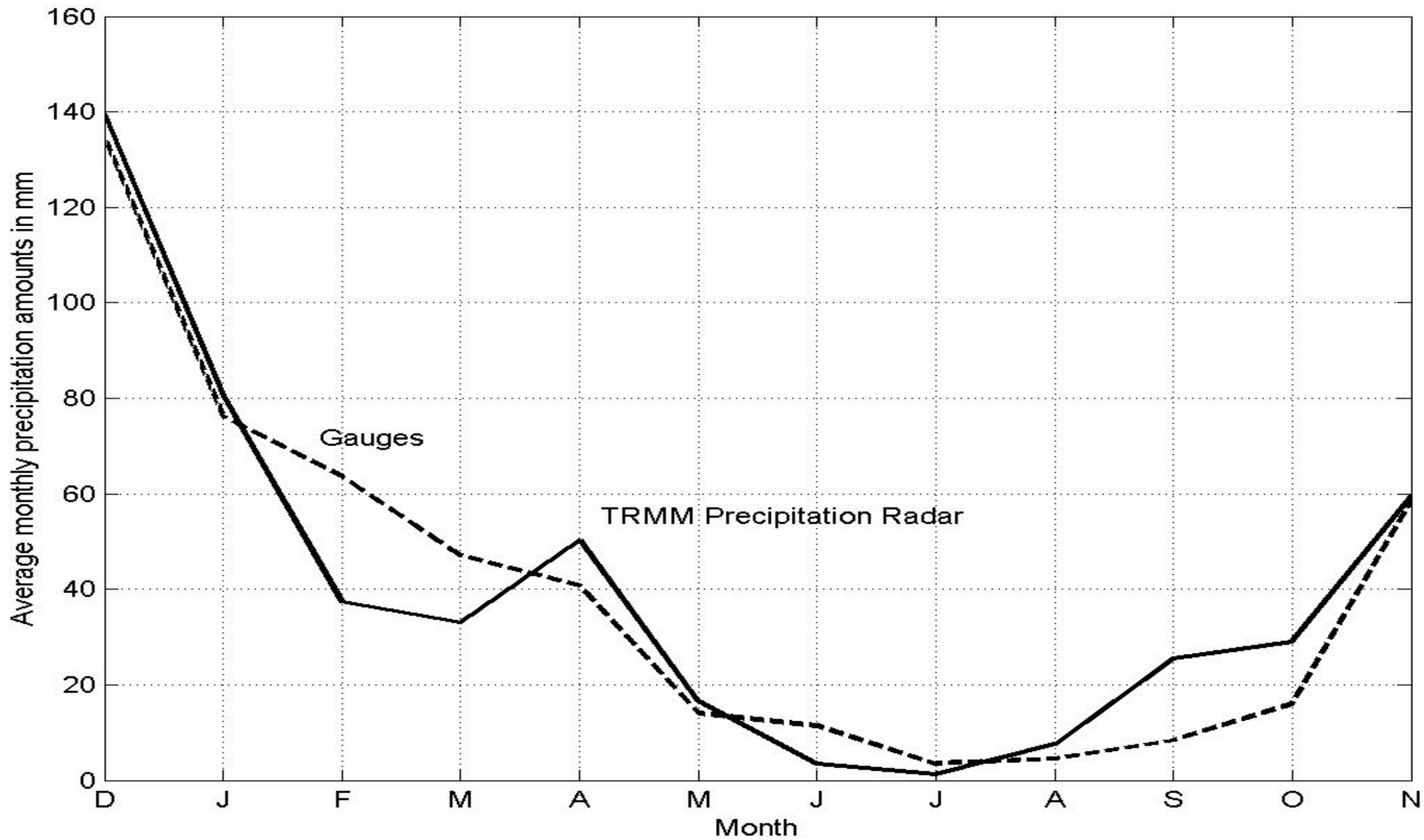
Comparisons of rainfall over daily, weekly or even monthly time scales suffer from the temporal sampling errors of the satellite whose revisit time is once or twice daily

The 3A25 dataset was used and compared with monthly values from the Rain gauge network and climatology (25 stations were used with long climatological records)

The 3A25 dataset is an accumulation of the TRMM 2A25 PR retrieval algorithm. This dataset contains monthly mean values of the surface rainfall rate.



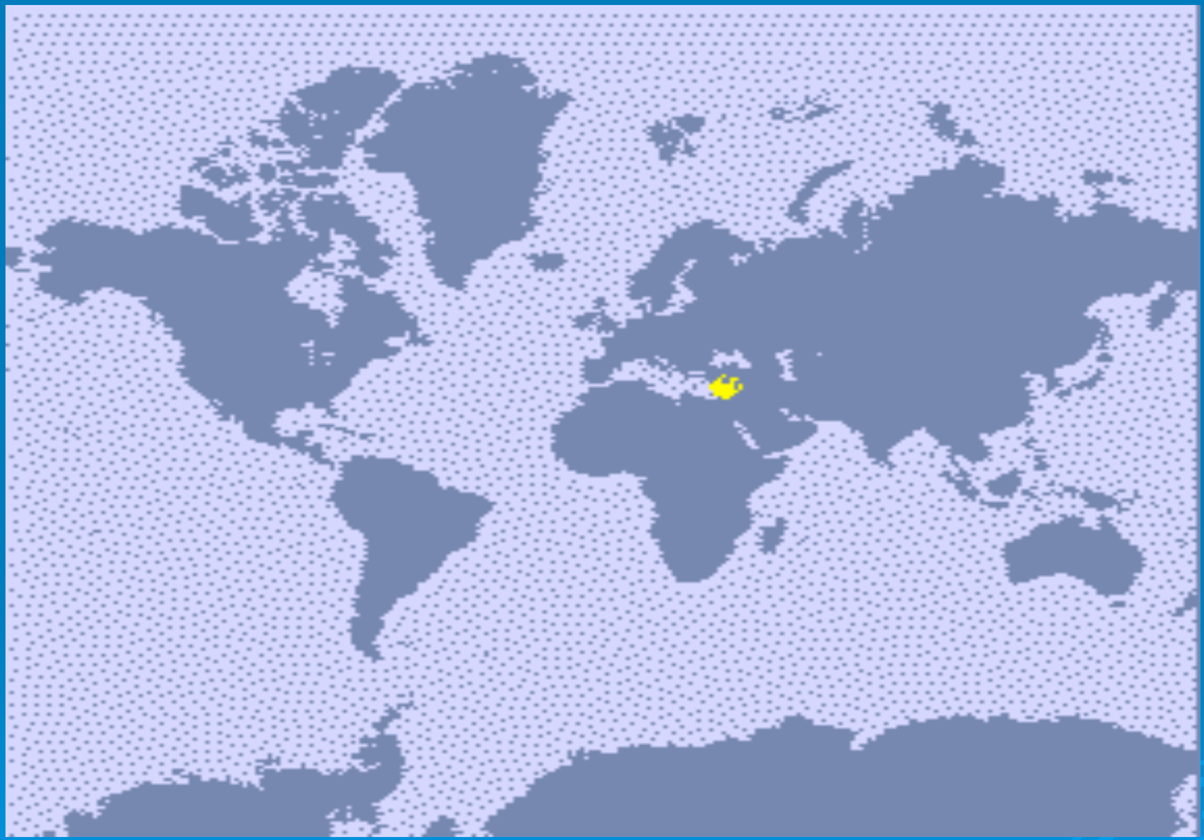
Climatological Rainfall Measuring Stations in Cyprus.



Five-year average monthly rainfall amounts (from Dec. 1997 to Nov. 2002) over Cyprus: TRMM Precipitation Radar (3A25) versus rain gauges. (Top) Linear scale: absolute difference comparison, “rainfall differencing”.

How we see potential future participation

in GV of GPM

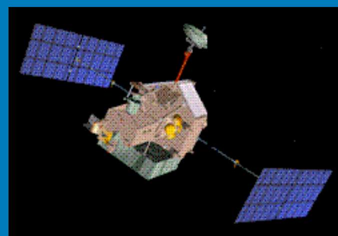


Participating in Ground Validation of GPM

Cyprus Meteorological Service:

- Use of the experience gained in Voltaire
- Use of the existing network of raingauges
- Use of a network of automatic raingauges (many already in place more under deployment)
- Use of the existing C-band radar (to be upgraded)
- Use of the planned X-band radar

GPM > 10 PR



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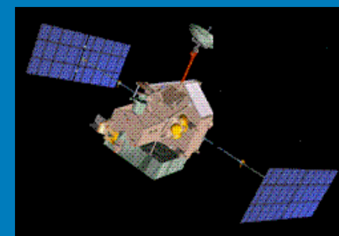
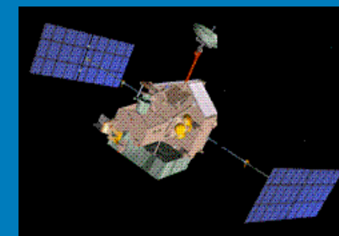




GR ~ 2

RG ~ 140 (35 auto)

. . .

After discussions with other Institutions in Cyprus there is an expression of interest in forming a local consortium which will be involved in future GV activities

Partners

- METEOROLOGICAL SERVICE OF CYPRUS

- CYPRUS UNIVERSITY OF TECHNOLOGY
  - New public university in Limassol

- THE CYPRUS INSTITUTE
  - **Newly founded research institute in Nicosia dedicated to applied research**

- SIGNAL GENERIX LTD.
  - R&D small company in Limassol specializing in wireless distributed sensors

Cyprus University of Technology (CUT)

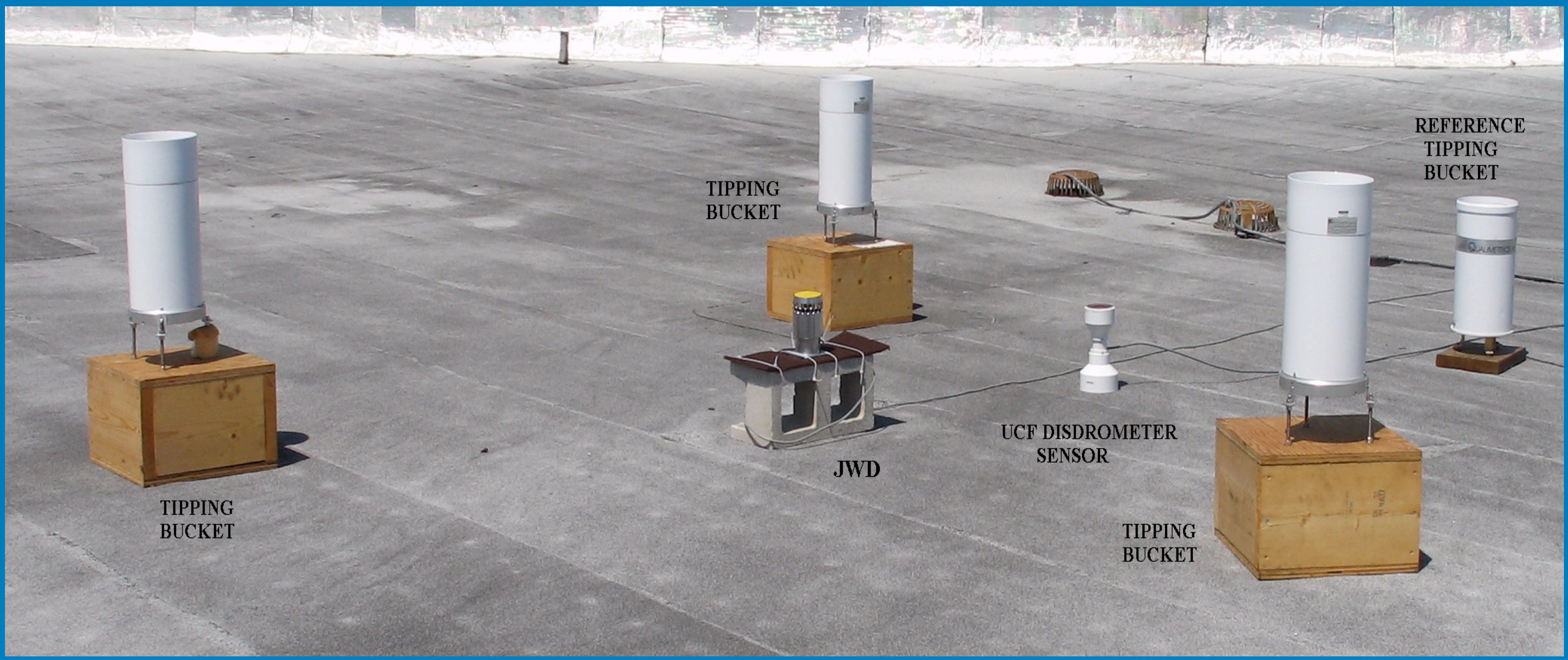
- **Partners at Cyprus University of Technology (CUT, Prof. Takis Kasparis) have experience in setting up and maintaining GV sites in Central Florida and in the data processing . Logistical support for:**
- **TEFLUN-B**
- **TEFLUN LBA**
- **CRYSTALFACE**
- **TRMM**

Also installed and maintained a dense rain gauge network

Instruments :

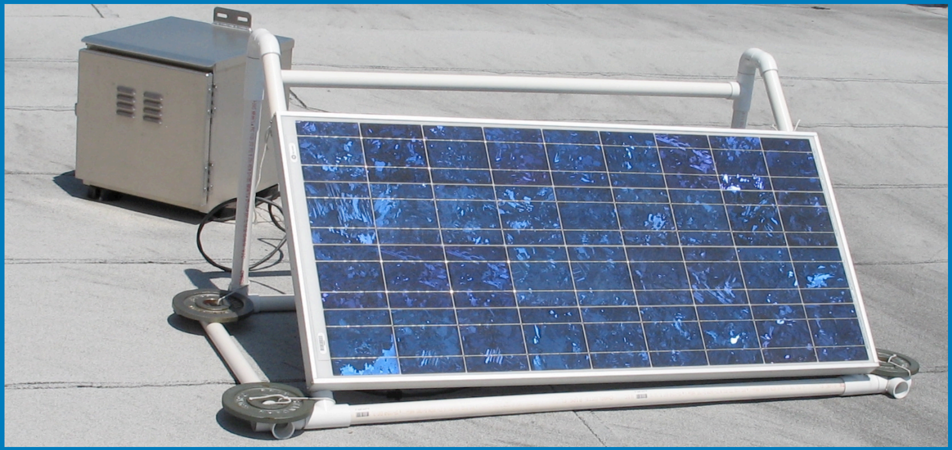
Rain gauges
Disdrometers
Radiosondes
NEXRAD

Data site at University of Central Florida, Orlando



- Rain gauge and Joss disdrometer data available in near real-time via FTP server.
- Similar site at Cocoa, Florida.

Additional Capabilities



Stand-alone operation at remote locations

Wireless access

R/D

Development of low-cost disdrometers can increase sampling density

CONCLUSION

Cyprus can play a role in GV building on experience, available and planned instrumentation and local expertise